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## WORKS RELATING TO THE LEVEL OF THE CASPIAN SEA

### WATER BALANCE OF CASPIAN SEA AND REASONS FOR ITS FALLING LEVEL

B. D. Zaykov

The perennial variations of the Caspian Sea level are cyclic in character. During the past 400 years, the level was highest from the 1740s to the middle of the 1810s, and is lowest at present. The perennial amplitude of the level variation reaches 5 meters.

Beginning in 1897, the drop of the level, which had reached 42 centimeters by 1930 and 233 centimeters by 1946, has been caused mainly by the below-normal surface flow, most of which is provided by the Volga River (80 percent). The period from 1930 to 1945 on the lower Volga was marked by its exceptionally low water of long duration, caused by the precipitation deficiency [see the following article by Bydin for the effect of low precipitation along the Volga upon the level of the Caspian Sea] in this period and the erratic behavior of discharge in the separate parts of its basin.

Low water in 1930 - 1945 was observed not only in the Volga River basin, but in the basins bordering it, the Ural and Don river basins, and in Western Siberia in the basins of the Irtysh and Tobol rivers. West, south, and east of this vast region, the average discharge was normal, and even more normal in the Dnepr, Angara, and Shilka rivers. The distribution of water in these rivers indicates that the low water of this period in the Volga basin was caused by large-scale atmospheric processes rather than being local in origin. In this period, an intensification of anticyclone circulation and a simultaneous intensification of cyclone activity in the periphery of the anticyclone was observed in the European SSR and in Western Siberia. When anticyclone conditions prevailed in the basins of the Volga, Tobol, Irtysh, and other rivers, precipitation decreased, but when cyclone activity became more intense on the periphery of the anticyclone area, precipitation increased.

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Two recently observed facts: (1) the weakening of the predominance of anticyclone influences in the Volga basin, and (2) the tendency of the air temperature to drop in the region of the Caspian Sea, give reason to believe that there will be no further substantial drop in the level of the Caspian Sea and that it may even rise slightly.

The variations of level act unfavorably upon the development of the economy and could be modified somewhat by regulating the influx. Potential problems in stabilizing the level should be defined in developing plans for the reconstruction of rivers of the Caspian basin.

## RAINFALL AS A HYDROLOGICAL CHARACTERISTIC IN ITS APPLICATION TO THE CASPIAN SEA

F. I. Bydin

As a first numerical criterion, the following approximate formula can be used in a number of regions, but not in all; $n = \lg(1+w_1) + \sqrt[3]{w_2}$, where n is the number of years in which the precipitation which has fallen influences the hydrological phenomenon under study, $w_1$ is the surface of the drainage area (in thousands of square kilometers) being analyzed, and $w_2$ is the surface of lakes in the drainage area (in thousands of square kilometers). The yearly precipitation in the Volga River basin, up to Stalingrad, as it influences the yearly level of the Caspian Sea was analyzed from this formula and the following coefficients of influence were obtained.

| Influence of Precipitation of a Given Year upon Level of Caspian in Given Year and in Subsequent Years | Coefficient of Influence |
|---|---|
| On Level of Given Year | 0.144 |
| " " 1 yr later | 0.175 |
| " " 2 yr later | 0.182 |
| " " 3 " " | 0.161 |
| " " 4 " " | 0.120 |
| " " 5 " " | 0.084 |
| " " 6 " " | 0.057 |
| " " 7 " " | 0.040 |
| " " 8 " " | 0.026 |
| " " 9 " " | 0.011 |
| " " 10 " " | 0.000 |

Data for the entire drainage area of the Caspian Sea is not available in literature, but since 80 percent of the discharge into the Caspian Sea is supplied by the Volga, the data introduced above, obtained previously by other researchers, is approximately accurate. The transformed precipitation values obtained, as compared with observed levels, are shown in the below figure. The figure demonstrates how well the transformed precipitation values correspond to the behavior of the level of the Caspian, in comparison with untransformed precipitation values.

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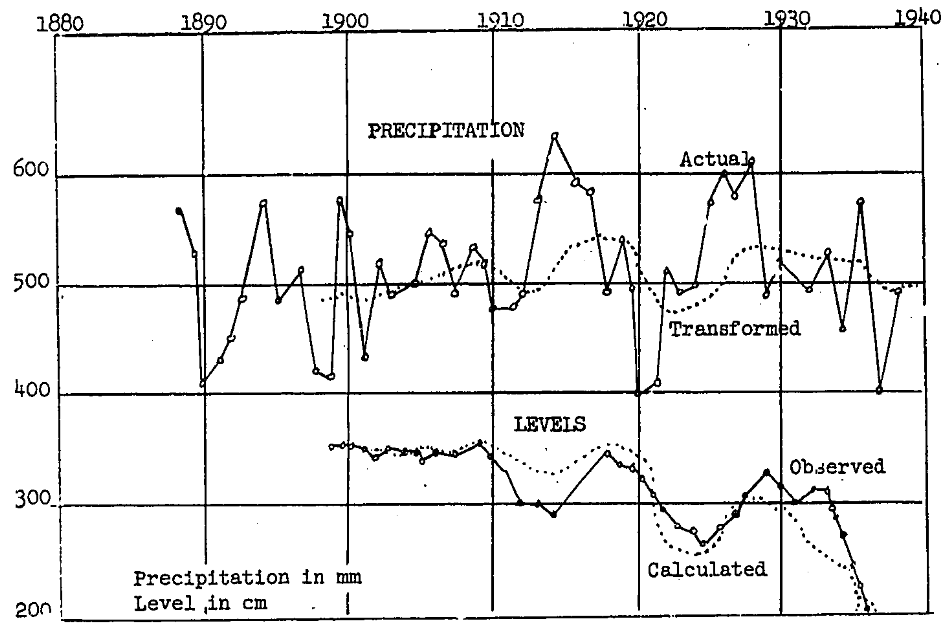


SEDIMENT FORMATION WITH REGARD TO DISTRIBUTION OF CARBONATES, IRON, MANGANESE, AND PHOSPHORUS IN CASPIAN SEA DEPOSITS

S. V. Bruyevich
Ye. G. Vinogradova

A study of the distribution of very mobile forms of the most important biogenous elements after carbon and nitrogen, i.e., iron, phosphorus, and manganese, in Caspian Sea deposits, determined by the method of hydrochloric extraction, used together with data on the distribution of carbonates, makes it possible to outline the basic characteristics of deposit formation in this sea.

The method of hydrochloric acid extraction was used to obtain data suitable for comparison with other analyses of deposits, sedimentary rocks, and soils, i.e., one-hour boiling in a water bath with 10 percent hydrochloric acid in the amount of 30 milliliters per 1-1.5 grams of dry bottom after preliminary solution of carbonates.

Comparative experiments made on typical sea bottoms (silts or sandy silts) showed that, under these conditions, the data for manganese and phosphorus remained practically unchanged when the concentration of hydrochloric acid varied from one to 30 percent. The amount of acid-soluble iron increased continuously as the concentration of hydrochloric acid was increased from one to 30 percent, which is connected with the breakdown of the ferroaluminosilicate complex. A study of nine analyses of deposits of the North Arctic Ocean, made by Heidenrich and cited by Boggid as applied to our calculations, led to the conclusion that the following amounts of elements are taken up in a 20 percent hydrochloric acid extract: potassium 17 percent, sodium, 19 percent, aluminum 28 percent, calcium 63.5 percent, ferric iron 74 percent, magnesium 80.5 percent, ferrous iron 95 percent, manganese dioxide and manganous oxide 100 percent, and phosphorus 100 percent. Thus, our data on phosphorus and manganese with a 10 percent hydrochloric acid extract is close to the absolute content of these elements in the bottom soil, while the data on iron is arbitrary and is about three fourths of the absolute value.

Tested were 192 specimens of marine deposits from 78 stations, including 50 stations on the northern Caspian, 16 on the middle Caspian, including the Zhiloy Island-Cape Kuuli section, and 12 on the southern Caspian. From the 78 stations, bottom monoliths, which were studied by layers, were taken at 25 with an Eckmann tube, including 11 on the Northern, 7 on the middle, and 7 on the southern Caspian Sea. The maximum length of the monoliths was 110 centimeters. The depths of the stations varied from 2 to 960 meters. The specimens were collected in the period from 1935 to 1940.

Caspian Sea deposits are fluviogenous (river erosions), thalassogenous (formed in the sea itself from the solution), and eolian, in order of importance. The amount of fluviogenous deposits, assuming that all the river discharge reaches the sea, is about 120 million tons, or about 300 grams per square meter of the sea bottom per year, considering the entire water space, excluding Kara Bogaz Bay. Undoubtedly, the amount of river discharge carrying suspensions which reaches the deep-water regions is the smaller part of the entire discharge. The amount of thalassogenous carbonates, with reference to calcium carbonate, is close to the amount of all thalassogenous deposits, and is about 82 grams per square meter per year, excluding Kara Bogaz Bay.

The manganese and phosphorus content in all marine deposits is very close and sometimes equal in weight, and their ratio never exceeds 2:1 or 1:2. The amount of acid-soluble iron is 20-50 times the amount of manganese or phosphorus. The deposits with respect to iron, manganese, and phosphorus content range in the following order: silts, sandy silts, sands, and shells. Thus, the highest content of acid-soluble forms of elements is connected with the fine fraction. The silts are most clearly local in composition, differing sharply in various regions of the sea.

In the silts of the northern Caspian, the average content of iron, manganese, and phosphorus is 1.68 percent, 0.053 percent, and 0.042 percent, respectively. The deposits of the Middle Caspian are divided into the low-carbonate silts of the western and central parts, which are influenced greatly by river discharge, and the high-carbonate silts of the eastern shoal. The content of acid-soluble forms of iron in the first is much greater than in the second; but this is less true with regard to manganese and phosphorus. The average content of iron for the western and eastern parts is equal to 3.12 and 0.60 percent, of manganese 0.067 and 0.020 percent, and of phosphorus, 0.067 and 0.037 percent.

The deposits of the underwater elevation connecting the Apsheron Peninsula with the eastern shore of the Caspian, especially in its central deep-water part, made up of ancient, now-eroding clays, are very close in their carbonate and iron content to the material due to erosion and losses borne by rivers of western shore of the middle Caspian. The silts of the southern Caspian in the western and central parts reflect river discharge influence (mainly the Kura River) and contain less iron, approximately as much phosphorus, and considerably more manganese than the silts of the western part of the middle Caspian. The silt of the deepest part of the southern Caspian (900-960 meters) contains an average of 2.70 percent iron, 0.103 percent manganese, and 0.060 percent phosphorus with a carbonate content of the upper layer of 19.4 percent ($CaCO_3$). This high manganese content is a basic characteristic of deep-water deposits of the southern Caspian.

Division of the middle and southern Caspian into western (plus the southernmost) and eastern parts, with a considerable river discharge in the west and none in the east, permits conclusion in regard to the chemical composition of the western (mainly fluviogenous deposits) and eastern (thalassogenous and eolian) parts.

Deposits of the various regions and bays of the eastern part show a drop in the absolute content of iron, manganese, and phosphorus with increase of the carbonate content. At the same time, the content of these elements with reference to the silicate skeleton remains constant. This indicates that the main part of these elements is derived from eolian rather than thalassogenous deposits. The average content of eolian deposits, calculated in this way, is about 2.9 percent iron, 0.08 percent manganese, and 0.15 percent phosphorus with reference to the silicate skeleton. Considering the average carbonate content of middle-Asiatic soils (the Golodnaya steppe and the Kara-Kum desert) to be about 16.5 percent carbon dioxide recalculated into $CaCO_3$, the average content of acid-soluble forms of the elements considered in eolian deposition on the Caspian Sea is 1.49 percent iron, 0.042 percent manganese, and 0.078 percent phosphorus. The average content of iron and phosphorus in the clay soils of the Golodnaya steppe and the Kara-Kum desert is 1.70 and 0.052 percent, respectively, according to Kossovich's data of 1909.

The low-carbonate deposits of the western part of the Caspian Sea, which also fill the basins of the middle and southern Caspian, are very homogeneous in composition and differ sharply from the deposits of the eastern part. Their composition must be very close to the average composition of suspensions in rivers of the western shore of the Caspian, which is confirmed by comparison with the few available analyses of river suspensions. The slightly higher carbonate content of deposits of the western part of the Caspian, in comparison with the available data on the carbonate content of river suspensions, forces the assumption that the authigenous carbonate deposition in the western part of the sea has some influence on the powerful sedimentation of deposits of fluviogenous origin.

Carbonates are first among the purely authigenous deposits of the sea, yielding 82 grams of $CaCO_3$ per square meter per year ($CO_2$ recalculated into $CaCO_3$, excluding Kara Bogaz Bay. Authigenous silicates are second, yielding 2.8 grams of silicon per square meter per year (excluding Kara Bogaz Bay). Phosphates dissolved in river discharge may yield up to 0.07 grams of thalassogenous phosphorus per square meter per year. Phosphorus of fluviogenous deposits makes up the greater amount of phosphorus, i.e., up to 0.18 grams per square meter per year, if all the river material reached the deep-water regions. At present, there is no data for calculating the thalassogenous deposition of iron and manganese; apparently, it takes place very nonuniformly in various parts of the sea, i.e., to a greater degree in the western part of the sea and to a much lesser degree in the eastern. Carbonates of fluviogenous deposits are very important in the total influx of carbonates into the sea; about 42 percent of the thalassogenous carbonates are brought in, in soluble form, with the river discharge. Eolian carbonates are also important, although probably do not constitute more than one-twentieth of the thalassogenous carbonates.

In the conditions of the Caspian Sea, fluviogenous deposits differ from the eolian and thalassogenous by the following characteristics of composition: considerably lower carbonate content of silts not containing shells (about 12-13 percent for deposits of the western shore of the middle Caspian and about 12-20 percent for deposits of the southern Caspian against 50-70 percent $CaCO_3$ for silts of the eastern shore), considerably higher content of acid-soluble iron and manganese, and close or slightly higher content of phosphorus. In percents of the silicate skeleton, the fluviogenous deposits are considerably richer in iron and manganese, but considerably poorer in phosphorus.

In monoliths of silts taken with an Eckman tube, the content of acid-soluble iron, manganese, and phosphorus is usually inversely proportional to the carbonate content, i.e., the ratio is the same as in the upper layer of the bottom. Going downwards, the carbonate content increases and the content of iron, manganese and phosphorus decreases. As in the upper layer of deposition, the increasing carbonate content in the deep layers is a "diluting" factor with respect to iron, manganese and phosphorus.

The vertical distribution of carbonates, iron, phosphorus, and manganese in a monolith of bottom is characterized by an increased in carbonate content and a decrease in the content of iron, magnesium, and phosphorus towards the bottom in Tyubkaragan Bay and to the north of Agrakhan Bay in the northern Caspian, in part of the central deep-water region of the southern Caspian, and in the region of the eastern slope and the eastern shoal of the southern Caspian.

Owing to the different tempo of deposit formation, the increase in carbonate content with depth in the shallow water regions of the northern and, partially, the southern Caspian, on one hand, and in the region of maximum depths and the eastern slope of the southern Caspian, on the other, must be related to quite different times. The decrease in carbonate content and the increase of silicate material in the upper layers of deposits are connected with the intensification of eolian components in a recent epoch, approximately the last thousand years, because of the intensification of eastern winds, which is in turn connected with the intensification of atmospheric circulation.

According to N. A. Belinskiy and G. P. Kalinin the intensification of atmospheric circulation causes a decrease in the discharge of the Volga and a drop in its level, and, consequently, a decrease in the influx of dissolved carbonates, which form thalassogenous carbonate deposits in the sea. Since the changes in the discharge of the Volga and Kura rivers are inversely related, when the discharge of the Volga decreases, the discharge of the Kura increases, and the carbonate content of the western and deep-water regions of the southern Caspian decreases. The increase in the region of delivery of Kura suspension deposits promotes an increase of the intensity of bottom compensation flow into the region of the sea bed when the east winds are intensified.

The study of such indicators of deposit formation as carbonates, iron, manganese, and phosphorus in present-day marine deposits and their dependence upon the conditions of deposit formation permits one to recreate the conditions of mineral deposit formation for the background of the geological past.

According to the data published by N. M. Strakhov and his collaborators (Doklady Akademii Nauk, Vol LII, No 6, 1944), we can assume that carbonate deposition in the western part of the Lower Permian lagoon of the Bashkir Urals took place under conditions of an extremely low influx of eolian material and an absence of river clastic material. The clays of the eastern part of the lagoon were brought in from the Urals because of erosion of very fine, highly-weathered sedimentary material, which was in part anomalously enriched with manganese and phosphorus. According to our analyses of limestones of the cliffs of Ust'-Urt in the region of Tyub-Karagan on Mangyshlak, these Neogene limestones were deposited in the main without the participation of river discharge.

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The reliability of deciphering the conditions of deposit formation in the geological past could be improved considerably if contemporary marine-deposit formation were clarified through the use of more extensive and variegated representative material.

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